1 Introduction

Purpose

The purpose of this manual is to provide guidance and recommended procedures for the preparation of *Commerce Business Daily (CBD)* announcements and contract provisions for use in acquiring the services of architect-engineer (A-E) firms to prepare and deliver computer-aided design and drafting (CADD) generated products.[1]

Future Additions and Updates

The content of the manual is intended to be neither static nor all-inclusive and thus will be updated and enhanced as appropriate. Suggestions for improvements are strongly encouraged so that subsequent updates will accurately reflect the input and needs of CADD users within the Department of Defense (DoD) Tri-Services. Recommendations or additions should be sent to the Tri-Service CADD/GIS Technology Center (CEWES-IM-DA) ATTN: Mr. Bobby Carpenter, U.S. Army Engineer Waterways Experiment Station, 3909 Halls Ferry Road, Vicksburg, MS 39180-6199 (telephone no. (601) 634-4572) (FAX No. (601) 634-4584) (email: carpenb@ex1.wes.army.mil).

Additional copies of the manual may be obtained through the Tri-Service CADD/GIS Technology Center. An electronic copy may be obtained from the Tri-Service CADD/GIS Technology Center's homepage on the internet at address http://tsc.wes.army.mil.

Applicability

This manual is applicable to all DoD Tri-Service contracting, project management, legal, and technical design personnel involved in the acquisition of the services of A-E firms to prepare and deliver CADD-generated products.

The manual provides a brief discussion of the basic CADD data preparation and delivery considerations which must be addressed prior to contracting for A-E CADD services. This release does not contain the recommended contract language for the accomplishment of each specific type of application (e.g., the acquisition of surveying data and the preparation of CADD drawings to be used for specific design phase activities (such as electrical, mechanical, civil site, and sanitary)).

The contracting of A-E services to acquire data and prepare electronic deliverables using, or to be used by, geographic information systems (GIS) will be addressed in Part 1.2 entitled "A-E GIS Deliverables Standards."

Background

Computer-aided drafting (CAD) technology was first introduced in the mid 1960's as a tool for the production of drawings without the use of

[1] A glossary of terms used in this report can be found in Appendix A.

traditional drafting tools. The drawings were created and displayed by manipulating graphic elements on the computer screen instead of drawing them by hand. Designers began to realize the benefits of CAD technology and the name was changed to CADD. CADD technology has become the preferred method for the preparation, distribution, storage, and maintenance of architectural and engineering type drawings.

Each of the Tri-Service agencies independently initiated efforts to establish CADD standards in the late 1980's. The Air Force Logistics Command (1989) released the *Architectural and Engineering Services for CAD Implementation Within Air Force Logistics Command.* Headquarters, Department of the Army (1990), published Engineer Manual 1110-1-1807, *Standards Manual for U.S. Army Corps of Engineers Computer-Aided Design and Drafting (CADD) Systems*. The Naval Facilities Engineering Command (1993) distributed its *Policy and Procedures for Electronic Deliverables of Facilities Computer-Aided Design and Drafting (CADD) Systems*.

In 1992, the Tri-Service CADD/GIS Technology Center (TSTC) was established at the U.S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. The TSTC has been tasked to consolidate and promote the use of CADD and GIS standards within the Tri-Services.

It has become Tri-Service policy to acquire CADD deliverables from A-E's to maximize the use of electronic digital data. Digital data are especially useful for life cycle management of an installation, from planning to facilities management. To further improve the use of digital data and to have the capability to share databases among the Tri-Services, graphic and nongraphic standards must be mandated. Standards are necessary to ensure that:

a. The CADD drawings and data created in one phase (e.g., design) are readily usable in the subsequent phases (e.g., facility management).

b. The CADD drawings and data are applicable for their intended use.

c. The CADD drawings and data are compatible with the available CADD equipment and software.

d. The CADD drawings and data created for one project, or project discipline, are compatible with those created for other projects.

e. The CADD drawings and data can be transferred and integrated with other applications, such as GIS, cost estimating, specification development, facility management, and environmental management and compliance.

f. The ultimate goal that CADD drawings and data generated at one Tri-Service installation will be consistent with those developed by another Tri-Service installation is reached.

g. The compatibility of the CADD drawings and data with pertinent national, international, and industry standards is maintained.

Target CADD System

The target CADD system consists of the platform (hardware and operating system), the CADD software (basic and application), and the database software (when applicable) currently used by the installation which will be receiving and using the CADD-generated drawings and data. It is recommended, but not required, that A-E's develop their CADD drawings and data using the specified target CADD system(s). However, it is of paramount importance that A-E's deliver the CADD drawings and data in a format "compatible" with the receiving installation's target CADD system. The advantages of using CADD technology will not be realized, and the expenditure of additional funds and labor will be necessary, if the electronic digital media is

delivered in a format which is not compatible with the installation's target CADD system.

Target Platforms

The two most common types of fundamental CADD platforms (i.e., hardware with installed operating system) currently used by Tri-Service installations are:

- UNIX workstations (i.e., networked computer workstations with a UNIX operating system).
- Personal computers (PC's) (i.e., stand-alone or networked PC's with "Intel compatible" (i.e., compatible with Intel's 286, 386, 486, or pentium) central processing units and a Microsoft (MS) Windows NT and/or 95 operating system.

Most CADD software packages available today have been developed to run on MS Windows NT and/or 95.

Target CADD Software

Basic CADD software

The two most dominant types of commercially available CADD software packages currently used by Tri-Service installations are AutoCAD (Autodesk) and MicroStation (Bentley). MicroStation and AutoCAD are "basic" CADD products in that they provide fundamental drafting and design capabilities.

CADD application software

CADD application software packages operate "on-top-of," or in conjunction with, the basic CADD software package (e.g., MicroStation and AutoCAD).

Advanced application packages assist in the performance of specialized design or analytical functions such as highway design, site design, architectural design, and survey/mapping. Some build and link nongraphic attribute data linkage into the graphic entities. Others maintain their data in external files or through external database engines. The advanced CADD software application packages, customer support libraries, user commands, and menus may be written platform-specific.

Extension application packages "extend" the capabilities of the basic CADD software. The extensions enhance drafting and modeling productivity or some other specific function.

"Neutral" file exchange formats

CADD graphic files copied to "neutral" file exchange formats such as drawing exchange format (DXF) and initial graphics exchange specification (IGES) can be read by both AutoCAD and MicroStation. However, caution should be exercised because the neutral file exchange formats may not transfer all of the graphical entities, or the data needed for analysis and further review. Basic CADD software packages and add-on or third-party CADD software application packages are typically employed to develop CADD drawings. None of the neutral file exchange formats currently available have reliable mechanisms to transfer the wide variety of nongraphic linkage mechanisms used in basic and advanced CADD software packages.

DXF supports the graphic entities supported by AutoCAD. The set of graphic entities available in IGES is sufficient to represent the graphics from almost any CADD software package. Both DXF and IGES file exchange formats will exchange two-dimensional drawings, two- and three-dimensional wireframe models, and simple three-dimensional surfaced solids. Notable problems occur with the use of fonted lines and nonstandard text fonts. Many problems can be prevented by avoiding the use of certain entities, converting entities to simpler forms, using simple and standard text fonts, and careful control of layering and symbology.

When translating to and from neutral file

exchange formats, each CADD package tries to transfer the appearance of the neutral file exchange format's graphic entities into the types of graphic entities it supports. This works well for simple graphical elements (e.g., lines, circles, and rectangles), but does not work well for all complex graphical elements. The neutral file exchange format's graphic entities which are not supported by the CADD package may be lost or modified when the neutral file is imported.

The linkages between the graphical and nongraphical entities may be lost when copying a file to a neutral file exchange format. Different CADD packages have different ways of storing nongraphical data. Some CADD packages can store a small amount of information with the element in an application-defined format, or alternatively, have one or more linkages to external databases where a larger amount of data can be stored.

Recommended Provisions for the Acquisition of A-E Contract Services

To acquire the services of A-E firms, Government agencies are required to follow the procedures defined in the *Federal Acquisition Regulations (FAR)*. The procurement process for a typical A-E design services contract consists of the following steps:

a. An initial advertisement is placed in the *Commerce Business Daily* containing project selection criteria.

b. A-E firms respond to the advertisement with a completed Standard Form 255 that outlines specific, specialized, project-related experience, and qualifications.

c. The Standard Form 255's are sent to a selection board for final evaluation.

d. The selection board develops a short list of three or four firms based upon the qualifications included in the Standard Form 255's and the selection criteria previously defined by the board.

e. Formal contact is made with the short-listed firms. This may include an office visit, an invitation to come to the installation and make a presentation, and/or a telephone interview. The formal contact procedure must be the same for each short-listed firm, and the selection board must ask each firm the same questions.

f. Based upon the findings of the formal contact, the short-listed firms are ranked. The single firm which received the highest rating is selected and this selection is announced to all of the firms that submitted Standard Form 255's.

g. The detailed administrative and technical contract provisions are submitted to the selected firm with a request for a proposal. An agreement is negotiated with the selected firm, and the A-E contract is awarded.

h. If no agreement can be negotiated with the selected firm, the selection board

will initiate negotiations with the next highest rated short-listed firm.

In the past, Government personnel and A-E's drafted survey, mapping, and design drawings by hand on a reproducible vellum or film material. Drafting standards were developed by the installations, or services, to ensure consistency and uniformity. Many installations had standard, hand-drafted designs and details which were provided to the A-Es for inclusion in their design drawings. The installation requesting the A-E services would include terminology referencing the appropriate drafting, drawing material, drawing size, and submittal specifications in the A-E contract technical provisions.

Today, equally clearly understood requirements and terminology must be included in the A-E contract's technical provisions for the use of CADD technology to prepare survey, mapping, and design drawings. This is generally accomplished in the following two steps. First, the requirement to prepare survey, mapping, and design drawings in an electronic digital format using CADD technology is included in the *CBD* announcement. Secondly, the more detailed formatting, drafting, and delivery instructions are contained in the technical contract provisions.

Sample clauses for inclusion in *CBD* announcements and the technical contract provisions requiring the use of CADD technology in preparing survey, mapping, and design drawings are included in Appendices B-E of this manual. The clauses are written around the requirements for AutoCAD and MicroStation because of their dominance in the commercial and Tri-Service markets.

CADD and GIS Integration Considerations

A decision should be made before the initiation of the A-E contracting procedures whether or not the CADD-generated survey, mapping, or design drawings and digital data will later be used with GIS applications. Both CADD and GIS technology can be used to create drawings and maps which have similar outward appearance.

CADD technology treats digital data as electronic drawings that are basically made up of graphic entities organized into “layers” or “levels.” CADD technology has become more sophisticated with the development of the capability to store basic nongraphic data about graphic entities in external databases. This nongraphical data can then be queried for design analysis or facilities management purposes.

GIS technology is more complex because it must accurately store both graphic (map or drawing) and nongraphic (database or attribute) data in a database for analysis and display purposes. GIS technology can be used to simulate extremely complex real-world events and situations.

At most installations, all electronic survey drawings, maps, and design drawings have been prepared using CADD technology. Today, with the growing popularity of GIS technology, the life cycle use of the electronic data should be evaluated in determining the most useful and efficient means for data collection and electronic map and drawing generation. Many installations use CADD technology for the development of electronic survey drawings and maps whose primary use will be in the development of design (architectural and engineering) drawings for construction type projects. GIS technology may be used for the development of all maps developed specifically for planning, design, operations, and facility management functions where the analysis of stored attribute data is the primary concern.

When the CADD-generated data files are to be later translated and used by a GIS system, the following guidelines in data structure should be followed:

a. The edges of all digitized maps must exactly match those of all adjacent drawings.

b. The digital representation of the common boundaries for all graphic features must

be exactly the same, regardless of level/layer. Each feature within a map theme must be represented by a single graphic element (e.g., polygon or line/string).

c. Lines/strings which represent the same graphic element must be continuous (i.e., not broken or segmented), unless that segmentation reflects a specific visual line type. Lines/strings representing the same type of data must not cross except at intersections.

d. Polygons must be closed (i.e., the first x- and y-coordinates must exactly match the last x- and y-coordinates). Each polygon must have a single unique centroid to which attributes (i.e., an attribute table) can be attached. Polygons of the same coverage must not overlap and must cover the area of interest completely (i.e., have no gaps in coverage).

e. All graphic elements that connect must exactly connect digitally, without overlaps or gaps.

f. Straight lines must be represented by only the beginning and ending x- and y-coordinate points. Lines/strings must not cross back on themselves or be of zero length.